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TECHNICAL NOTE 2299

EXPOSURE TESTS OF GALVANIZED-STEEL-STITCHED
ALUMINUM ALLOYS

By Fred M. Reinhart

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SUMMARY

Sheets of 24S-T3 and alclad 24S-T3 aluminum alloys joined to themselves by stitching with galvanized steel wire were exposed in a marine atmosphere and in the tidewater to determine whether they would have a satisfactory service life in these environments. Both alloys joined by this method are satisfactory with respect to corrosion resistance for service in marine atmospheres. The alclad 24S-T3 alloy is satisfactory for short periods of time, where the installation is subject to frequent wetting by sea water. The use of 24S-T3 sheet joined by stitching with galvanized wire is not satisfactory when subject to wetting by sea water.

INTRODUCTION

This report is the final report on one phase of an investigation undertaken to determine the corrosion rates of aluminum and magnesium alloys used in aircraft, after exposure to weather and in the tidewater. It is a summary of results of an investigation made to determine the corrosion behavior of 24S-T3 and alclad 24S-T3 aluminum alloys joined to themselves by stitching with zinc-coated high-carbon steel wire.

This investigation was conducted by the National Bureau of Standards under the sponsorship and with the financial assistance of the National Advisory Committee for Aeronautics.

TEST SPECIMENS AND PROCEDURE

Panels of 24S-T3 and alclad 24S-T3 aluminum alloys were stitched together with galvanized steel wire. The panels (0.040 by 4 by 14 in.) were assembled from two pieces each 0.040 inch by 4 inches by 8.5 inches with an overlap of 4 by 1.5 inches at the faying surfaces in the mid-section of the panel. They were stitched together by the Harris-Seybold-Potter Company with zinc-coated (hot-dipped), high-carbon steel wire.

conforming to Aeronautical Specification AN-W-13. The steel wire contained from 0.82 to 0.95 percent carbon and 0.3 to 0.4 percent manganese and was coated with a minimum of 0.70 ounce of zinc per square foot of surface.

Four panels of each alloy (24S-T3 and alclad 24S-T3) were exposed in the tidewater and three panels of each were exposed in the marine atmosphere at the Naval Air Station, Hampton Roads, Virginia, on August 1, 1944. Panels were removed from the tidewater after exposure periods of 6, 11, 22, and 37 months and from the marine atmosphere after periods of 11, 22, and 37 months.

RESULTS

The results of the tests discussed in this report are confined to macroscopical and microscopical examinations of the specimens after exposure.

Tidewater Exposure

24S-T3 panels.- After 2 months of exposure there was no evidence of rusting but there were white corrosion products on the zinc coatings of the steel wires used to staple the 24S-T3 panels. These zinc coatings disappeared entirely after 6 months of exposure and the staples were covered with a dark adherent rust (fig. 1). Examination of cross sections of the staple wires showed that they were pitted (fig. 2).

Crevice corrosion which started at the faying surfaces of the lap joint of the 24S-T3 alloy penetrated the sheet within 6 months as shown in figure 3. The rapidity of this attack was caused, at least partially, by the susceptibility of the sheet material to intergranular corrosion (fig. 4).

Microscopic examination also disclosed that the sheets directly underneath the staples had cracked by stress corrosion (fig. 5). The cracks started at the faying surfaces of the sheets. Since it is fairly well-established that tensile stresses are necessary for stress corrosion, the occurrence of stress-corrosion cracking is considered as evidence that some tensile stresses existed at the faying surfaces. These internal stresses undoubtedly were imposed by the pressure exerted by the clamping action of the staples, as the cracks originated on the surfaces of the sheets directly under and farthest away from the staples.

The condition of the staples and the 24S-T3 sheets after 37 months of exposure in the tidewater is shown in figures 6 and 7. The staples were much more rusted and pitted than those after 6 months of exposure.

(Compare figs. 2 and 8.) Crevice corrosion had not only penetrated the sheet but also the accumulation of corrosion products had built up sufficient pressure to cause the sheets to fracture (fig. 6).

Stress-corrosion cracks were also present on the 24S-T3 sheets underneath the staples after 10, 22, and 37 months of exposure, examples of which are shown in figures 9 and 10 after 37 months of exposure. These cracks also had their origins on the tension or faying-surface sides of the sheets. Typical intergranular corrosion also is shown in figure 10.

Alclad 24S-T3 panels.- There was zinc remaining on the staples used to fasten the alclad 24S-T3 sheets together after 6 months of exposure as shown by the presence of thin white corrosion products (fig. 1). The comparatively lesser attack of the staples on the alclad samples than in the case of the 24S-T3 is attributable to the fact that the difference in potential, in sea water, between commercially pure aluminum (2S) and zinc is less than that between aluminum-copper alloys and zinc. Examination of cross sections of the staples showed that there was no attack on the base metal as evidenced by the absence of pitting (fig. 11).

The staples in the alclad 24S-T3 panel were still a dark grayish red in color after 37 months of exposure, indicating that some of the zinc-iron alloying layers were still present (figs. 12 and 13). This observation was substantiated by microscopic examinations of cross sections of the staples which showed that they were just beginning to pit (fig. 14).

There were no corrosion products between the faying surfaces of the alclad sheets and no pitting of the alclad layers, indicating little, if any, crevice corrosion. Also, no evidence of stress-corrosion cracking was found on the alclad 24S-T3 panel after 6 months of exposure. After 11 months of exposure most of the alclad layers at the faying surfaces had disappeared as a result of corrosion but the core material had not been attacked. After 22 months of exposure the core material underneath the alclad layers at the faying surfaces was still free from attack. However, after 37 months of exposure the core was pitted at the faying surfaces and one area of stress-corrosion cracking was found (fig. 15).

Marine-Atmosphere Exposure

The galvanized staples on both the 24S-T3 and the alclad 24S-T3 panels were still coated with gray corrosion products after 37 months of exposure in the marine atmosphere, indicating that zinc or zinc-iron alloy layers were still present (figs. 16 to 19). There were a few places where the staples had darkened but none where red rust was detected.

There was no significant pitting of the underlying steel on any of the staples as shown in a typical cross section (fig. 20).

There was some slight pitting of the sheets at the faying surfaces of the 24S-T3 panel but no evidence of intergranular corrosion or stress-corrosion cracking was found after 37 months of exposure in the marine atmosphere. The anodic layers on the alclad 24S-T3 sheets were pitted at a few areas at the faying surfaces but in no case had the pits corroded to half of the thickness of the layers.

There were small amounts of corrosion products between the faying surfaces of the 24S-T3 panel and practically none between those of the alclad 24S-T3 panel, which indicated only mild crevice corrosion.

CONCLUSIONS

Sheets of 24S-T3 and alclad 24S-T3 aluminum alloys stitched together with galvanized steel wire were exposed for varying lengths of time in a marine atmosphere and in the tidewater to determine whether they would have a satisfactory service life. From results of these tests, the following conclusions may be drawn:

1. Zinc-coated, high-carbon steel wires (AN-W-13) used to join unanodized 24S-T3 aluminum-alloy sheets by steel stitching rusted between the third and sixth month of exposure in the tidewater at Hampton Roads, Virginia. Under the same exposure conditions the staples used to join the alclad 24S-T3 sheets darkened in color between the eleventh and twenty-second months but they were just beginning to show evidence of pitting after 37 months of exposure. The zinc was not completely removed from the staples in the 24S-T3 and alclad 24S-T3 panels after 37 months of exposure in the marine atmosphere.

2. The use of 24S-T3 sheet joined by such wires is not recommended under service conditions entailing wetting by sea water. Alclad 24S-T3 material joined with zinc-coated wires will give considerably longer service and therefore is to be preferred under these conditions.

3. This method of fabrication was satisfactory with respect to corrosion resistance for both 24S-T3 and alclad 24S-T3 for exposure in the marine atmosphere.

4. Because of the crevice corrosion observed at the faying surfaces of the joints it is recommended that they be protected. A nonabsorbing type of sealing compound or paint should be used to fill the joints. This sealing treatment may be applied either during or after the joining procedure.

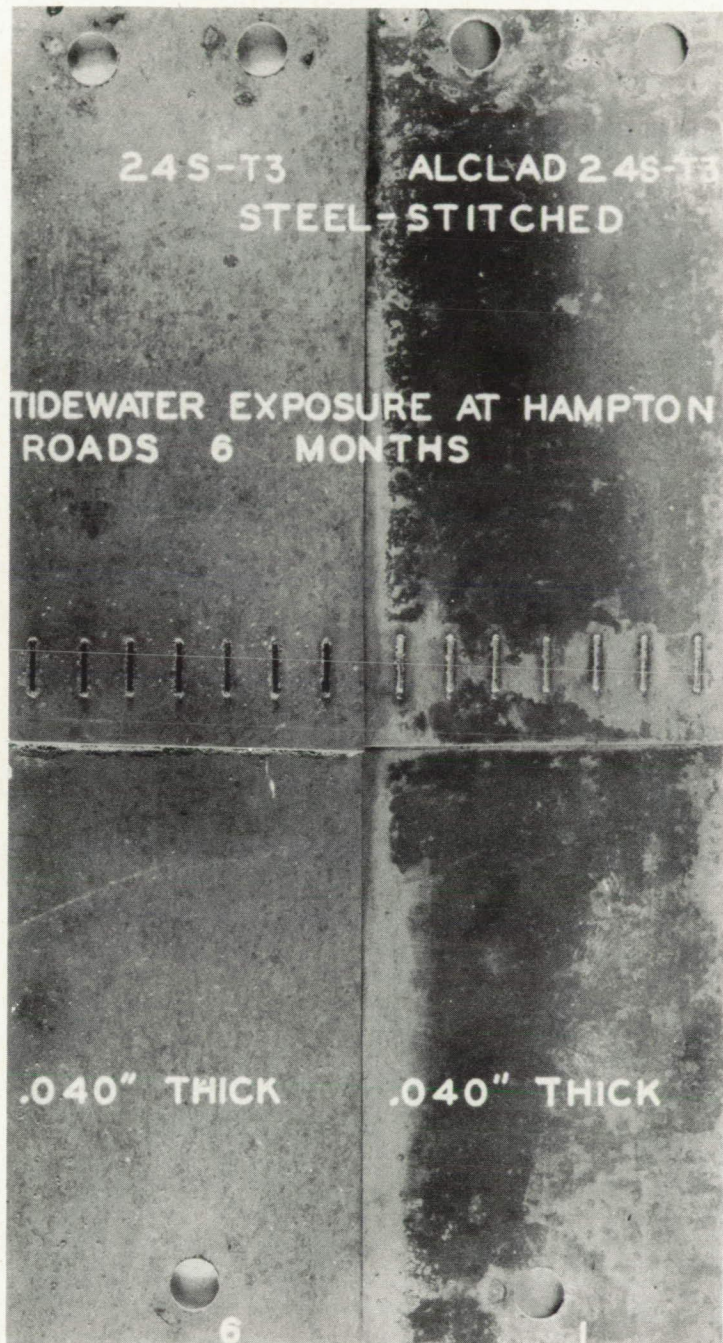


Figure 1.- The zinc coating had corroded off the wires on the 24S-T3 panel and they were rusted after 6 months of exposure in the tidewater. The zinc coating was still present on the wires of the alclad 24S-T3 panels as indicated by the presence of white corrosion products. Note the corrosion products emerging from between the faying surfaces on the 24S-T3 panel. Half size.

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Figure 2.- Pitting on zinc-coated steel wires on 24S-T3 panels after 6 months of exposure in the tidewater. X50.

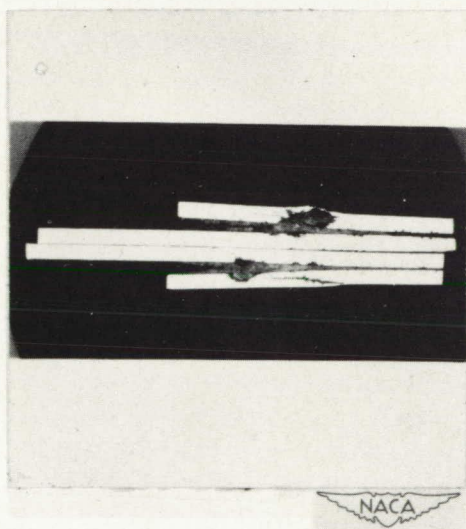


Figure 3.- Crevice corrosion starting at the faying surfaces penetrated the 24S-T3 sheets in less than 6 months of exposure in the tidewater. Longitudinal sections. X2.

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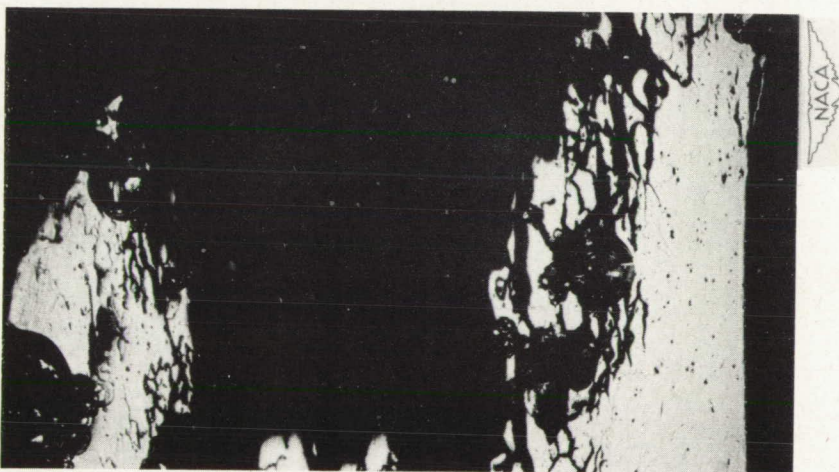


Figure 4.- Area of complete penetration of 24S-T3 sheet by intergranular corrosion which originated at the faying surface. Tidewater, 6 months. X50.

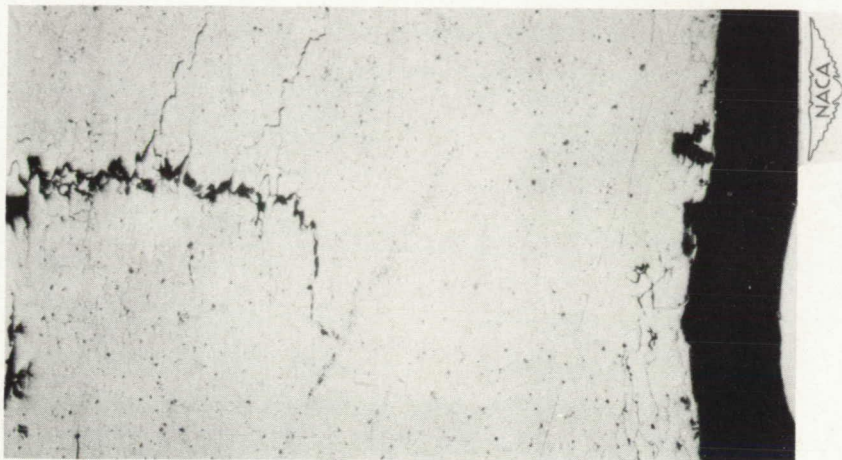


Figure 5.- Stress-corrosion crack through 24S-T3 sheet originating at faying surface, directly underneath prong of staple, partially shown at bottom. Tidewater, 6 months. X100.

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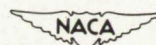


Figure 6.- Stapled portion of 24S-T3 panel after 37 months of exposure in the tidewater. Zinc coatings are gone from the staples and crevice corrosion which started at faying surfaces of lap joint has penetrated sheet. The sheet also is exfoliated. Actual size.

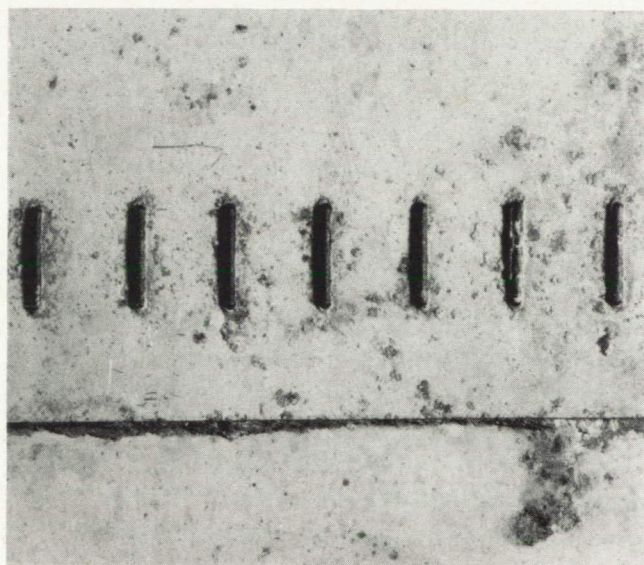


Figure 7.- Opposite side of panel shown in figure 6. Note corrosion products at edge of lap joint. Actual size.

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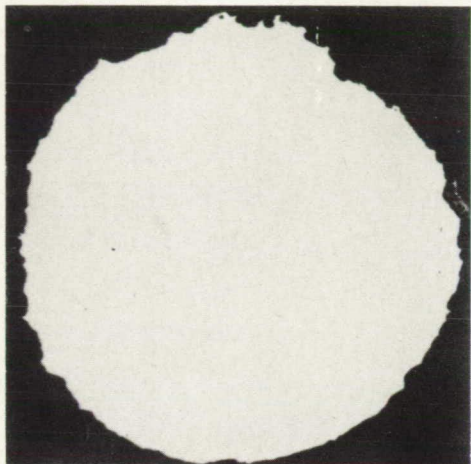


Figure 8.- Cross section of zinc-coated staple in 24S-T3 showing corrosive attack after 37 months of exposure in the tidewater. Compare severity of pitting with that in figure 2. X50.

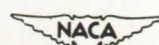


Figure 9.- Stress-corrosion crack in 24S-T3 which originated at faying surface of sheet opposite staple after 37 months of exposure in tidewater. X100.

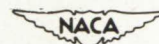
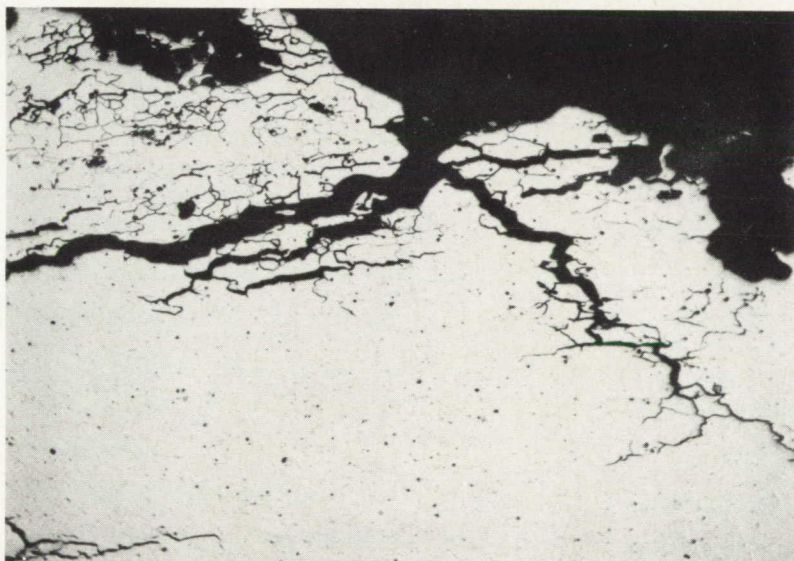


Figure 10.- Stress-corrosion cracks and intergranular corrosion in 24S-T3 sheet after 37 months of exposure in the tidewater. Only bottom of stress crack remains and nearly half the thickness of the sheet has corroded away. X100.

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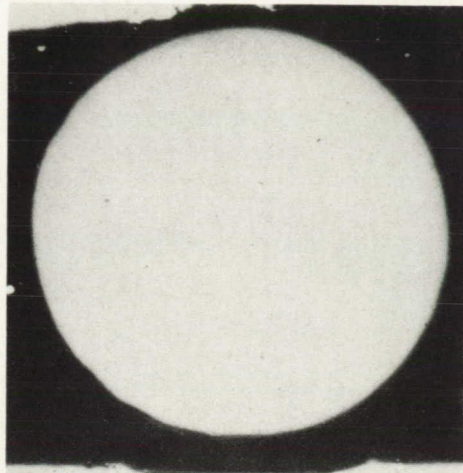


Figure 11.- Cross section of zinc-coated staple on alclad 24S-T3 panel after 6 months of exposure in the tidewater. Underlying steel uncorroded. X50.



Figure 12.- Stapled portion of alclad 24S-T3 panel after 37 months of exposure in the tidewater. Tops of staples are a dark grayish red, indicating that some of the zinc-iron alloy layer is still present. Actual size.

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Figure 13.- Opposite side of panel shown in figure 12. There is still considerable gray color on much of the area of the staples. Actual size.

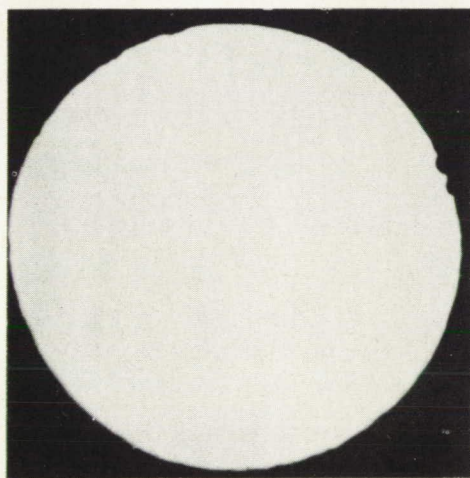


Figure 14.- Cross section of zinc-coated staple in alclad 24S-T3 after 37 months of exposure in the tidewater. Two pits in circumference are the only evidence of the disappearance of the zinc coating. X50.

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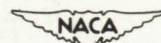
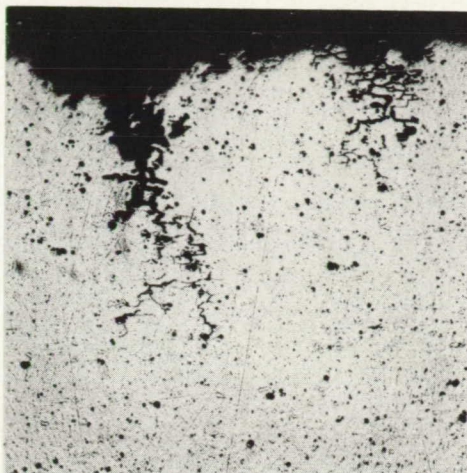


Figure 15.- Stress-corrosion cracks starting at faying surface of alclad 24S-T3 sheet after 37 months of exposure in the tidewater. Cracks were directly opposite staple and alclad layer had corroded off. X100.

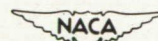
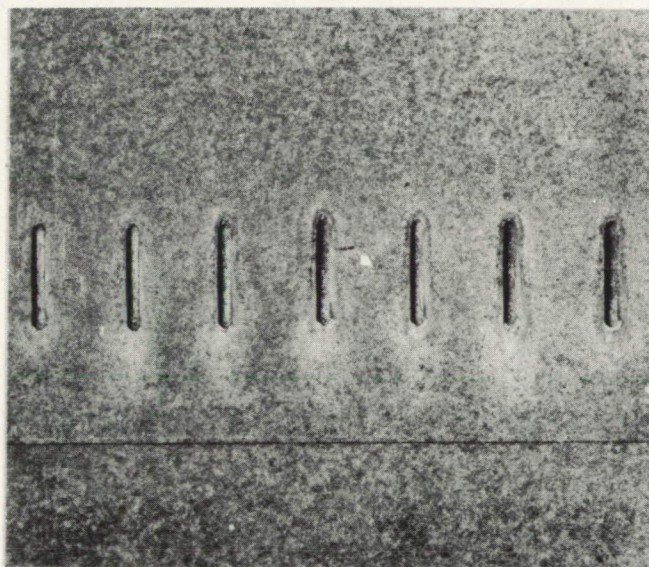


Figure 16.- Skyward surface of stapled portion of 24S-T3 panel after 37 months of exposure in the marine atmosphere. Gray color of staples indicated that some zinc was still present. Actual size.

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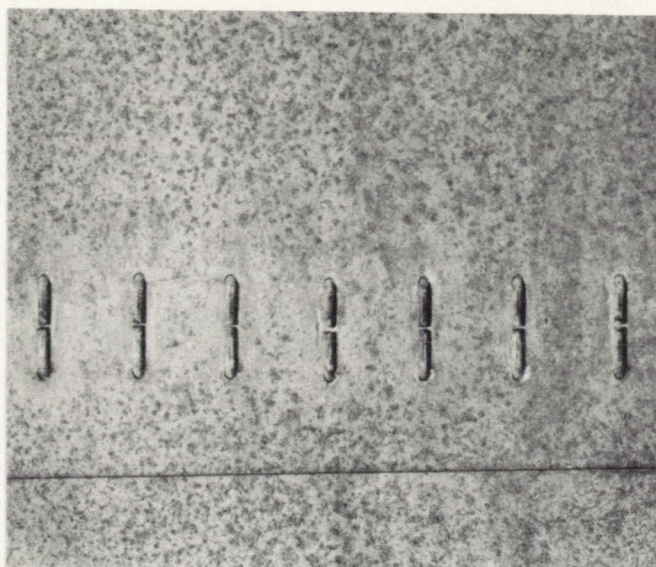


Figure 17.- Earthward surface of panel in figure 16. Portions of some staples were blackish gray, indicating that the zinc-iron alloy layer was exposed. Actual size.

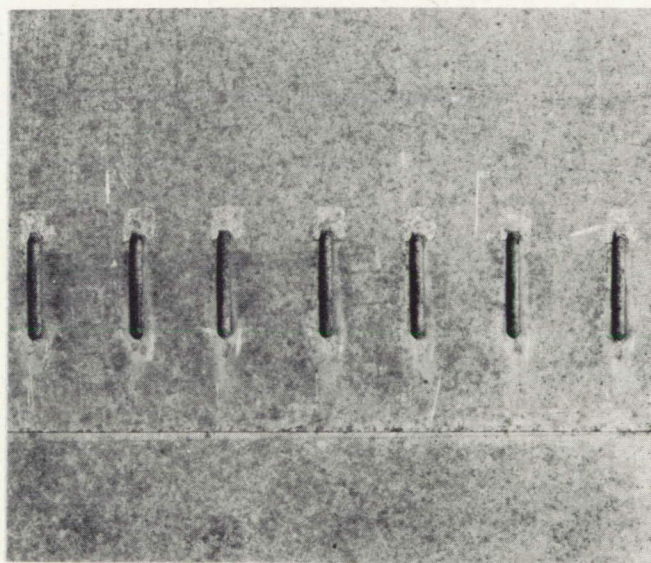


Figure 18.- Skyward surface of stapled portion of alclad 24S-T3 panel after 37 months of exposure in the marine atmosphere. Gray color of staples indicated that some zinc was still present. Actual size.

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Figure 19.- Earthward surface of same panel as in figure 18. Portions of some staples were blackish gray, indicating that the zinc-iron alloy layer was exposed (second staple from the right). Actual size.

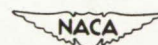
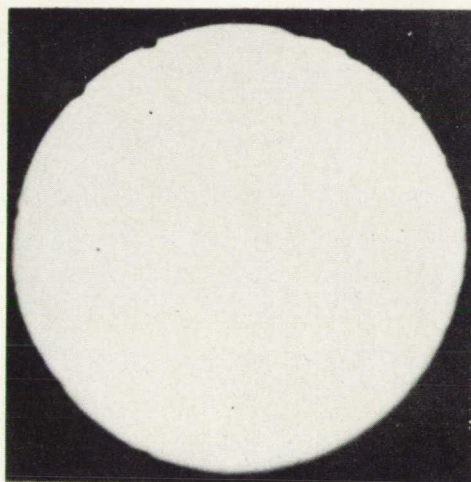


Figure 20.- Cross section of zinc-coated staple in 24S-T3 after 37 months of exposure in the marine atmosphere. There is no significant pitting of the steel base metal. Typical of staples on all panels exposed in marine atmosphere. X50.